Spring 2022 STAT:7500 SML : J. Huang

STAT:7500 Statistical Machine Learning (Spring 2022)

**Time and Location** MWF 12:30 PM-1:20 PM, 75 SH.

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**Prerequisites** STAT:5100 or STAT:5200, or equivalent courses.

**Office Hours** MWF 1:30 PM-2:30 PM or by appointment.

**References**
- Current papers on the topics discussed in the class will be suggested.

**Exams and projects** There will be no in-class exams, but there will be a final project. For the final project, each student is expected to give an oral presentation based on a paper on a topic of your interest related to the course materials in the final week of the class. The presentations will be given during the week before the final exam week.

**Homework** There will be about 6 homework projects. Project 1 involves implementation of an algorithm for solving lasso type of problems, all the remaining ones require substantial computational effort with neural networks.

**Attendance** Attendance at lectures and participation in discussions are expected. Failure to attend class regularly will affect your grade.

**Grading** Grading will be determined by homework grades. Scale runs like the following (and I may adjust it a little): A (90-100), B (75-89), C (55-74), D (40-54). A plus-minus grading system will be used.

**Course Objectives**
To equip Ph.D. students in statistics, biostatistics and related fields with a solid background in statistical machine learning that will be helpful to their future work in statistics and data science.
Topics to be covered (tentative)

1. High-dimensional statistics
   (a) High-dimensional linear models
      • Regularization: ridge regression, lasso and related methods
      • Algorithms: coordinate descent and semi-smooth Newton
      • Sparsity and non-asymptotic error bounds
      • Computation
      • Homework 1: (a) Performance of Lasso in linear and nonlinear regression models; (b) Comparing coordinate descent and semismooth Newton algorithms.
   (b) High-dimensional nonparametric statistics

2. Supervised learning
   (a) Classification
      • Basics: classification loss functions
      • Deep neural networks: Convolutional Neural Networks
      • Computation
      • Homework 2: classification using CNN with benchmark datasets: MNIST and CIFAR10
   (b) Regression
      • Basics: nonparametric regression with least squares loss
      • Deep neural networks: Multilayer perceptrons
      • Convex losses: robust regression, quantile regression
      • Computation
      • Homework 3: Neural regression with benchmark datasets: to be determined.
   (c) Prediction: assessment of prediction uncertainty
   (d) Theoretical properties
      • Approximation power of deep neural networks
      • VC-dimension of deep neural networks
      • Non-asymptotic excess error bounds

3. Optimization
   (a) Difference between learning and optimization
   (b) Challenges in neural network optimization
   (c) Gradient computation: backpropagation
   (d) Stochastic gradient descent
   (e) Computation
   (f) Homework 4: SGD for fitting regression models with neural networks: least squares regression and logistic regression.

4. Generative learning
(a) Nonparametric density estimation
(b) Discrepancy measures for probability distributions: $f$-divergences, Wasserstein distances
(c) Learning by distribution matching: connection with maximum likelihood
(d) Generative adversarial networks (GAN)
(e) Wasserstein generative adversarial networks (WGAN)
(f) Variational autoencoder (VAE)
(g) Computation
(h) Homework 5: Image generation using benchmark datasets: MNIST, CIFAR10 and others.

5. Conditional generative learning
   (a) Nonparametric conditional density estimation
   (b) Conditional generative learning: noise outsourcing
   (c) Application: classification, nonparametric regression
   (d) Computation
   (e) Homework 6: Conditional image generation and reconstruction using benchmark datasets: MNIST, CelebA and others.

6. Self-supervised and semi-supervised learning
   (a) Deep clustering of high-dimensional data
   (b) Self-supervised learning
   (c) Semi-supervised learning
   (d) Computation
   (e) Homework 7: MNIST and other datasets.

7. Representation learning (time permitting)
   (a) Supervised representation learning: sufficient representation learning
   (b) Unsupervised representation learning
   (c) Transfer learning and domain adaptation
   (d) Computation
ATTENDANCE AND CLASSROOM EXPECTATIONS
Students are responsible for attending class and for knowing an instructor’s attendance policies, which vary by course and content area. All students are expected to attend class and to contribute to its learning environment in part by complying with University policies and directives regarding appropriate classroom behavior or other matters.

ABSENCES
Students are responsible for communicating with instructors as soon they know that an absence might occur or as soon as possible in the case of an illness. Delays in communication could result in a forfeit of what otherwise might be an excused absence.

ABSENCES: ILLNESS, UNAVOIDABLE CIRCUMSTANCES, AND UNIVERSITY SPONSORED ACTIVITIES
Students who are ill, in an unavoidable circumstance affecting academic work, or who miss class because of a University sponsored activity are allowed by UI policy to make up a missed exam. Documentation is required by the instructor except in the case of a brief illness. Students are responsible for communicating with instructors as soon as the absence is known (https://opsmanual.uiowa.edu/students/absences-class#8.1).

ABSENCES: HOLY DAYS
The University is prepared to make reasonable accommodations for students whose religious holy days coincide with their classroom assignments, test schedules, and classroom attendance expectations. Students must notify their instructors in writing of any such Religious Holy Day conflicts or absences within the first few days of the semester or session, and no later than the third week of the semester. If the conflict or absence will occur within the first three weeks of the semester, the student should notify the instructor as soon as possible. See Operations Manual 8.2 Absences for Religious Holy Days for additional information.

ABSENCES: MILITARY SERVICE OBLIGATIONS
Students absent from class due to U.S. veteran or U.S. military service obligations (including military service-related medical appointments, military orders, and National Guard Service obligations) must be excused without penalty. Instructors must make reasonable accommodations to allow students to make-up exams or other work. Students must communicate with their instructors about the expected possibility of missing class as soon as possible. (For more information, see https://opsmanual.uiowa.edu/iv-8-absences-class\%C2\%A0-0).

ACADEMIC MISCONDUCT
Plagiarism and the process for addressing academic misconduct of graduate students are defined in Section IV, Article F “Plagiarism by Graduate Students” of the UI Graduate College Manual of Rules and Regulations. Please contact the CLAS Associate Dean for Graduate Education for any necessary assistance in navigating the process mandated by the Graduate College.

ACADEMIC ACCOMMODATIONS
The University is committed to providing an educational experience that is accessible to all students. If a student has a diagnosed disability or other disabiling condition that may impact the student’s ability to complete the course requirements as stated in the syllabus, the student may seek accommodations through Student Disability Services (SDS). SDS is responsible for making
Letters of Accommodation (LOA) available to the student. The student must provide a LOA to the instructor as early in the semester as possible, but requests not made at least two weeks prior to the scheduled activity for which an accommodation is sought may not be accommodated. The LOA will specify what reasonable course accommodations the student is eligible for and those the instructor should provide. Additional information can be found on the SDS website. Note that accommodations are not granted retroactively but from the time of the student’s request to the instructor onward. Graduate students serving as Teaching Assistants, Research Assistants, or Fellows must contact Faculty and Staff Disability Services (https://hr.uiowa.edu/support/faculty-andstaff-disability-services) for assistance with accommodations.

CLASS RECORDINGS: PRIVACY AND SHARING
Course lectures and discussions are sometimes recorded or live-streamed. These are only available to students registered for the course and the intellectual property of the faculty member. These materials may not be shared or reproduced without the explicit written consent of the instructors. Students may not share these recordings with those who are not enrolled in the course; likewise, students may not upload recordings to any other online environment. Doing so is a breach of the Code of Student Conduct and could be a violation of the Federal Education Rights and Privacy Act (FERPA); also see https://dos.uiowa.edu/policies/code-of-student-life/.

COMMUNICATION: UI EMAIL
Students are responsible for all official correspondences sent to their UI email address (uiowa.edu) and must use this address for any communication with instructors or staff in the UI community (Operations Manual, III.15.2). Emails should be respectful and brief, with complex matters addressed during the instructor’s drop-in hours, for example. Faculty are not expected to answer email after business hours or during the weekends.

FREE SPEECH AND EXPRESSION
The University of Iowa supports and upholds the First Amendment protection of freedom of speech and the principles of academic and artistic freedom. We are committed to open inquiry, vigorous debate, and creative expression inside and outside of the classroom. Visit Free Speech at Iowa for more information on the University’s policies on free speech and academic freedom: https://freespeech.uiowa.edu/.

COMPLAINTS ABOUT ACADEMIC MATTERS
Students with a complaint about a grade or a related academic matter should first visit with the instructor and then with the course supervisor (if applicable), and finally with the director of the school, department, or program offering the course. If a graduate student has not been able to resolve the issue through the director of the school, department, or program, they should contact the associate dean for graduate education in the College of Liberal Arts and Sciences.

FINAL EXAMINATION POLICIES
The final exam schedule is published during the fifth week of the fall and spring semesters or on the first day of summer classes; students are responsible for knowing the date, time, and place of their final exams. Students should not make travel plans until knowing this information. A student with exams scheduled on the same day and time or who have more than two final exams on the same day should visit this page for how to resolve these problems by the given deadline (https://registrar.uiowa.edu/makeup-final-examination-policies). No exams are allowed the week before finals, but with some exceptions made for labs, language courses, and off-cycle courses (https://registrar.uiowa.edu/final-examination-scheduling-policies).

HOME OF THE COURSE
The College of Liberal Arts and Sciences (CLAS) is the home of this course, and CLAS governs the policies and procedures for its courses. Graduate students, however, must adhere to the academic deadlines set by the Graduate College. See https://grad.uiowa.edu/academics/deadlines.

MENTAL HEALTH Students are encouraged to be mindful of their mental health and seek help as a preventive measure or if feeling overwhelmed and/or struggling to meet course expectations. Students are encouraged to talk to their instructor for assistance with specific class-related concerns. For additional support and counseling, students are encouraged to contact University Counseling Service (UCS). Information about UCS, including resources and how to schedule an appointment, can be found at counseling.uiowa.edu. Find out more about UI mental health services at: mentalhealth.uiowa.edu. Student Health can also address related concerns (https://studenthealth.uiowa.edu/). These visits are free to students. After hours, students are encouraged to call the Johnson County Community Crisis Line at (319) 351-0140 or dial 911 in an emergency.

NON-DISCRIMINATION STATEMENT
The University of Iowa prohibits discrimination in employment, educational programs, and activities on the basis of race, creed, color, religion, national origin, age, sex, pregnancy, disability, genetic information, status as a U.S. veteran, service in the U.S. military, sexual orientation, gender identity, associational preferences, or any other classification that deprives the person of consideration as an individual. The university also affirms its commitment to providing equal opportunities and equal access to university facilities. For additional information on nondiscrimination policies, contact the Director, Office of Institutional Equity, the University of Iowa, 202 Jessup Hall, Iowa City, IA 52242-1316, 319-335-0705, oie-ui@uiowa.edu. Students may share their pronouns and chosen/preferred names in MyUI, which is accessible to instructors and advisors.

SEXUAL HARASSMENT
The University of Iowa prohibits all forms of sexual harassment, sexual misconduct, and related retaliation. The Policy on Sexual Harassment and Sexual Misconduct governs actions by students, faculty, staff and visitors. Incidents of sexual harassment or sexual misconduct can be reported to the Title IX and Gender Equity Office or to the Department of Public Safety. Students impacted by sexual harassment or sexual misconduct may be eligible for academic supportive measures and can learn more by contacting the Title IX and Gender Equity Office. Information about confidential resources can be found here. Watch the video for an explanation of these resources.